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Experimental Study on Water Production Function for Waterlogging Stress on Corn

Wang Kuang^a, Yuan Xianjiang^a, Cao Xiuqing^a, Xue Yafeng^b, a*^a *Anhui Water Resources Research Institute, Zhihuai Road 771 Postcode 233000, China*^b *Anhui Water Resources Commission, Donghai Road 3055 Postcode 233001, China*

Abstract

Trough experimental study on combined controlling of surface and subsurface water logging in undisturbed test pits where corn planted, the study results show that the corn yield was decreased, meanwhile, the height of corn and the day of tasseling and silking were respectively inhibited and delayed for Seedling and jointing stage water logging. The susceptibility factors in four phases of corn are ranked, and the susceptibility order of different corn stage is Seedling>jointing>tasseling-silking>maturity. The parameters of water production functions are determined by field data observed in experimental station of Anhui Institute of Water Resources. Through statistic test, the model is reasonable and easy-to-use. Composite indexes from water logging such as SFEW50 are helpful for drainage system design and for operation & maintenance of the drainage farmland project in Huaibei plain.

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Key words: water production function; corn; water logging; experimental study ;

1. Introduction

Agricultural drainage technology is an important Mitigation measure by adjusting the water status of farmland waterlogging [5]. Over the years, many experts and scholars have done a lot of researches on farmland drainage measures and process simulation. Scientists in some countries, such as the United States, Japan, Netherlands, France and other countries from the 1970s began to study indicators of farmland drainage and drainage related to the preparation of the specification[1][2][4]. Domestic research, such as the cylinder test by Anhui Water Resources Research from 1956 to 1958, was carried out in all rice

*Corresponding author: Wang Kuang. Tel.: +0-552-305-6046

E-mail address: wangkuang81@163.com; kuangk.wang@gmail.com

growth period flooded trial. Then, scientific and Technological Achievements such as drainage indexes had been applied in drainage design of Jiangxi province; many research institutions have already focused on this area since 1990s, such as Wuhan University, Shen Rongkai, Wang Xiugui established by the water production function [8][12], Wenji, Wang Shaoli put forward crop drainage indicators [11]; Anhui IWHR's Tang Guangmin proposed waterlogging index CSDI and CW concept of weight coefficients with its solution [10]; Yangtze University, Zhu Jianqiang shows how to identify cases of waterlogging [15]. Most of these scholars, just study critical growth stages of different crops, such as soybean flower and pod, cotton flower and boll stage [6][7]. On the full stages of corn waterlogging has not been systematically studied. Based on Xinmaqiao irrigation station's series of data, the paper analyzed at different growth stages of corn of yield reduction under waterlogging stress, and its drainage indicators and relative yield of the calculation model are established. It provides some decision references to promote the coordinative development among waterlogging control and groundwater table decrease, flood control, irrigation, water resources utilization and improving ecological environment, make unified plans and comprehensive control in the basin, and further exert the synthetic benefit of Huaihe River harness.

2. Material and method

2.1. Method of experiment

Anhui Province, Xinmaqiao irrigation station is located in the center of the territory of Huaibei Plain, longitude 117 ° 22 ', latitude 33 ° 09', locating at semi-humid monsoon climate zone. The method of experiment is waterlogging in still survey pit. The transect of survey pit is square whose size is 6.67m²×1.8m. There is 0.3m depth of sand filter and the system of water supply and drainage in the bottom of each pit where has 4 rows of corn. In 2009, each measuring pit with 32 corn seedlings, field management and the control group test pits are the same. In corn, the seedlings stage, jointing stage, tasseling and silking stage, and grain filling stage were implemented last 2d, 4d flooding treatment, flood depth of 7cm. Soil moisture was controlled in a suitable region where soil water is between 65% and 80% of field capacity except waterlogging. Depth of flooding, flood water, soil nutrients, weather, plant height, yield and other growth and development of other experimental data were observed. Irrigation and natural rainfall simultaneously made groundwater level rise above ground level about 7cm, and water level stayed design time till the waterlogging test finishes. Six days after flooding, ground water accordingly rise to the depth of 80cm.

2.2. Method of experiment

The stress imposing on plant by excessive soil water in the root zone is quantified by the *SEW* concept which was introduced by Sieben (1964). This factor is calculated by measuring the duration and the water table levels less than critical level only are considered, so the sum represents a measure of the exceedence of the critical level. The *SEW* factor expresses stress of groundwater, whereas *SFW* factor which expresses inundated degree indicates a calculated water depth caused by designed rainfall. The two indexes are calculated as [1] [2];

$$SEW_x = \sum_{i=1}^m (x - d_i) \quad (1)$$

$$SFW = \sum_{i=1}^n h_i \quad (2)$$

$$SFEW_{xi} = SEW_{xi} + SFW_{xi} \quad (3)$$

Where x=critical level, and is generally chosen the 30cm or 50cm [6]; di = the i day of groundwater depth, cm; m= the number of days of depth to groundwater back to the control level, d; SFW=cumulative depth of surface water; n= the number of flooding days; hi = the i day of surface depth, cm.

The improved model as follows[8][17]:

$$\text{Improved Jensen model: } \frac{y}{y_m} = \prod_{i=1}^N \left(\frac{AX_i - SFEW_{xi}}{AX_i} \right)^{\lambda_i} \quad (4)$$

$$\text{Improved Blank model: } \frac{y}{y_m} = \sum_{i=1}^N a_i \left(\frac{AX_i - SFEW_{xi}}{AX_i} \right) \quad (5)$$

$$\text{Improved Stewart model: } \frac{y}{y_m} = 1 - \sum_{i=1}^N b_i \left(\frac{SFEW_{xi}}{AX_i} \right) \quad (6)$$

$$\text{Improved Singh model: } \frac{y}{y_m} = \sum_{i=1}^N c_i \left[1 - \left(\frac{SFEW_{xi}}{AX_i} \right)^2 \right] \quad (7)$$

2.3. Data analysis

SPSS17.0 software was used to analyze the data. Analysis of univariate analysis of variance (One-way ANOVA) revealed flooded duration effect on the yield of wheat. If the main effect was significant, then Duncan multiple comparisons were carried out to test whether the difference of the wheat production among the treatments was significant.

3. Analysis of result

3.1. The impact of flooding on corn

Tests show that height of corn plant was inhibited after flooding treatments in such as seedling or jointing periods, and the longer flooding days lasting, the shorter plant height was. In seedling stage treatment, plants lasting 4 days of flooding treatment height were the shortest, see Figure (1). Moreover, after flooding treatments in Seedlings stage, the date of corn jointing, tasseling, silking and harvesting were delayed. Indeed, the treatment of lasted 4 days during seedling stage and jointing stage, the relative of plant height of each treatment compared to the control group were 53.7cm, 27.0cm gap, and the date of jointing delayed 2 days, tasseling or silking was delayed 2 to 6 days, harvest time was 5 days delayed. Whereas, maturity stages could bear waterlogging longer than other stage treatments, and also plant height and growth stage delay was not obvious.

Systematic analysis of experimental data and statistical results show that the corn stage of seedling is the most sensitive to waterlogging. Also, as we can be seen from Table 2, flooding stress on corn has significant impact on corn yield. The treatments of seedling continuous flooding 2 days and 4days, yield

reduction are obvious, respectively 25.8% and 67.1% yield decrease; followed the jointing stage, flooding 2 days and 4 days, yield reduction reached 26.1%, 34.7%; In tasseling to silking stage flooding lasting 2 days and 4days, yield reduction was 10.8% and 25.0%; maturity stage flooding 4 days yield reduction was just only 4.9%, the weakest. With the number of days flooded, corn reductions are to different degrees at different growth stages. To 4-day flooding during growth periods of corn, the laws of yield reduction are in order, following as: seedling> jointing> tasseling silking> maturity. Therefore, we can conclude that the capacity of corn resistance to flooding tends to increase with the growth of plant.

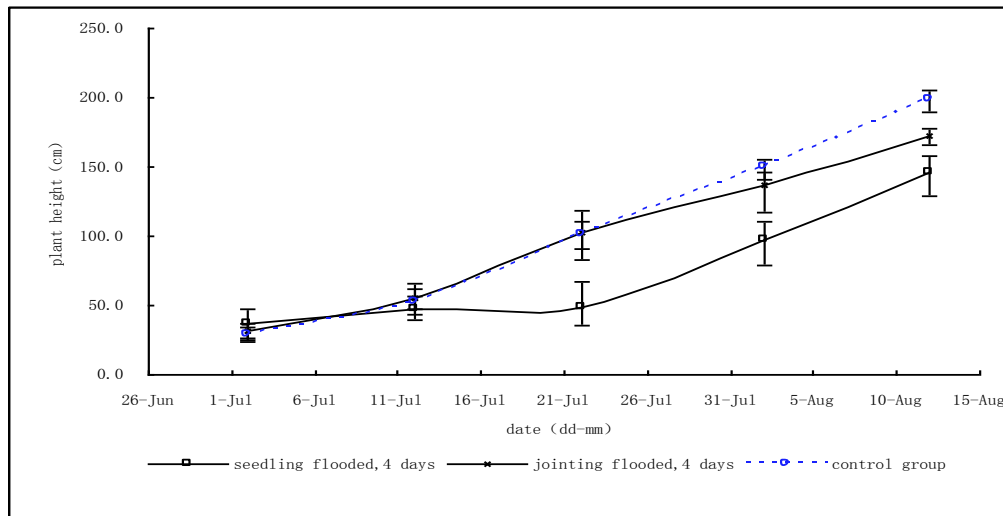


Fig.1. Progress of corn height growth from seedling and jointing water logging

Table1. Waterlogging stress on corn yield

| Growth period | Treatment | Depth of flooding (cm) | During the flooding (d) | Corn yield (kg/pit) | Relative yield (%) |
|-----------------------|----------------|---------------------------|----------------------------|------------------------|-----------------------|
| Seedling | W ₁ | 7 | 2 | 3.13±0.22bc | 74.2±5.2 |
| | W ₂ | 7 | 4 | 1.39±0.36d | 32.9±8.5 |
| Jointing | W ₃ | 7 | 2 | 3.12±0.17bc | 73.8±4.0 |
| | W ₄ | 7 | 4 | 2.75±0.27c | 65.3±6.4 |
| Tasseling and silking | W ₅ | 7 | 2 | 3.76±0.15b | 89.2±3.6 |
| | W ₆ | 7 | 4 | 3.16±0.31bc | 75.0±7.3 |
| Maturity | W ₇ | 7 | 2 | 4.09±0.03ab | 96.9±0.7 |
| | W ₈ | 7 | 4 | 4.01±0.08ab | 95.1±1.9 |
| control group | W ₉ | / | / | 4.22±0.09a | 100.0±2.1 |

Note: Different letters show significant differences ($p < 0.05$).

3.2. Determine the water production function of corn

The experimental data has been taken into improved crop water production function model (4) - (7), and then there are four factors regression analysis. The results are shown in Table 2. In addition, (4) - (7) of the input data are y , y_m , and (x taken 50cm). And X_i according to experimental observation were collected from the seedling stage which each of them are 36 days, 11days, 18 days, 28 days. The regression shows that Jensen, Blank, Stewart and Singh model coefficients are significant. Furthermore, R^2 is greater than 0.9, indicating that water production functions are with high accuracy level under the conditions of waterlogging.

Table 2. The parameters of water production functions

| model | Sensitivity parameters (λ_i , a_i , b_i , c_i) | | | | R^2 | F |
|---------|---|----------|-----------------------|----------|-------|--------|
| | Seedling | Jointing | Tasseling and silking | Maturity | | |
| Jensen | 3.756 | 0.981 | 0.464 | 0.192 | 0.981 | 38.537 |
| Blank | 0.658 | 0.981 | 1.280 | 1.185 | 0.981 | 38.500 |
| Stewart | 2.681 | 0.939 | 0.513 | 0.208 | 0.939 | 11.617 |
| Singh | 0.555 | 0.978 | 0.950 | 0.996 | 0.978 | 33.327 |

Note: $F_{0.05}=6.608$, $F_{0.01}=16.258$. Different letters show significant differences ($p < 0.05$).

4. discussion

1) The new crop water production function models have been established under waterlogging stress conditions, the models' parameters (λ_i , a_i , b_i , c_i) are based on all data processed by the statistical test to be determined, and comprehensively reflect the different growth stages of crops to waterlogging sensitivity. Carried on the F-test, models are reasonable.

2) Jensen model under flooded conditions was reported fewer^[12], whereas Blank model, Stewart and Singh model are the new forms of water production function in waterlogging condition especially applying in corn. Through experiments to determine the parameters are easier to achieve. Thus, the type of crop water production function under flooded conditions will be widely applied in the practical applications.

3) Water production function parameters are different with time-domain and geographical variability^[14]. Due to drainage conditions, crop water production function research in China has just started, so, the accumulation of data is limited, and the time-domain variability of function parameters is still needed to further studied. In addition, goals of farmland drainage from the single-objective indicators of the red line of food safety to the direction of a multi-objective control, such as taking into account ecological, environmental, regional equity^{[13][20][22]}. Therefore, it should be taken ongoing experiments of farmland drainage.

5. Conclusion

There is co-existence of drought and waterlogging disasters in Huaibei Plain. And also, so many flood plains distribute along the Huaihe River with particularly frequent flood. In this study, the result provides a scientific basis and technical support to drainage system design and operation-management.

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